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EXPERIMENTAL, CHARACTERIZATION AND EVALUATION OF VARIOUS COMPOSITE MATERIALS FOR AUTOMOBILE COMPONENTS

VIPAN KUMAR & RAMNEEK SHARMA

Department of Automobile Engineering, Chandigarh University, Gharuan, India

ABSTRACT

The aim of this work deals with the microstructure and the mechanical properties of silicon carbide, zirconium dioxide (SiC, ZrO_2) reinforced aluminum metal matrix composite. Aluminum metal matrix composite of varying silicon carbide, zirconium dioxide content (2, 5) percentage of weight fraction were prepared by bottom stir casting technique. The composite material can be widely used in automobile industries in place of currently used materials in automobile components. Various experiments such as Rockwell hardness, Brinell hardness, tensile strength, impact (charpy, izod) test have been performed in order to study the various characteristics and mechanical properties. The mechanical testing of fabricated composite material is performed and the mechanical properties are compared with the pure aluminum metal. The comparison of various mechanical properties of experimental materials with currently employed materials in the automobile industry. Structural material characterization of the fabricated composite was also performed by scanning electron microscopy and microstructures have also been carried out.

***KEYWORDS**: Materials, Stir Casting Technique, Hardness Tensile Strength, SEM, Microstructure & Mechanical Properties*

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Original Article

INTRODUCTION

Composites materials are the combination of two or more constituent material having different physical and chemical properties with characteristics different from individual components [1]. They commonly consist of a continuous phase called matrix and discontinuous phase in form of silicon carbide and zirconium dioxide or particle are called reinforcement. Composite materials have light in weight and better properties as compared of pure metal [2]. The aluminum composite is widely used in a structural application, the transportation sector, automobile sector.

In now's a day the modern technology required materials with light in weight, better mechanical properties, and high tensile strength. Aluminum metal matrix composite material comprises high melting temperature light in weight and good wear resistance properties [3]. The aluminum metal matrix has become the required material is a various application like as aerospace and automobile components such as engine piston, cylinder liner, brake, disc /drum etc.[4]

Aluminum metal matrix reinforcement with silicon carbide, zirconium dioxide is a novel composite which is used in automobile components (brake pads and brake rotor, engine, piston, brake disc). The automobile industry is doing research and experiment into reducing the overall weight of car improve safety and cost is less [5] many researchers concluded that new composite material hasbetter properties and performance. The microstructure of zirconium dioxide, silicon carbide reinforcement aluminum alloy produced by a molten method.

It shows the stability of silicon carbide and zirconium dioxide is the variety of manufacturing processes melt was found to dependent on the matrix. This work aims to prepare and studying mechanical properties of aluminum metal matrix composite material, reinforced by (2, 5 wt. %) silicon carbide, zirconium dioxide particles using bottom stir casting. The details about components made of composite material as shown in table 1

But now's a day the aluminum composite is prepared by bottom stir casting. Different composition of the silicon carbide and zirconium dioxide were selected with the aluminum. Mechanical testing of the fabricated sample was performed and a comparison result is also presented. For experimental material surface analysis, SEM result also performed for structural characterization of the prepared sample.

Scanning electron microscopy images of all the specimens subjected tensile strength is examined.

Table 1: Detailed about Composite Material used in Automobile Components

S.No	Name of Parts	Material Used	Material Grades	Method of Manufacturing
1	Propeller shaft	Steel and aluminium	SAE8620, AA5182, AA5454	casting
2	Piston ring	Cast iron and chrome steel	EN18,EN19,AW6060,AW6082	casting
3	Brake rotor	Cast iron	AL6082,A356,EN198	casting
4	Gear box	Steel, aluminium	AA5454,AL7075,SAE8620,	casting
5	Brake disc	Cast iron, steel, nickel	SAE1541,SAE1041,A356,S58C	casting
6	clutch	Aluminium, high carbon steel	Al6063,AL6024,EN47	casting
7	Engine valve	Nickel, chromium, iron, alloy	A356,AW6082,EN198,SAE1548	casting
8	Cylinder liner	Cast iron, alloy, chromium, manganese	AL7075, Mg, AL6082, EN47	casting
9	Sensor, nut and bolt	Aluminium, plastic, brass	AL2024, B16	casting
10	bearing	Chrome steel	SAE52100	casting
11	Connecting rod	Nickel, alloy, iron	Al6061,EN18,EN24	forging

EXPERIMENTAL MATERIALS

The material is selected in study AL6061T6, silicon carbide, zirconium dioxide. Aluminium 6061T6 in solid form used as metal matrix and silicon carbide, zirconium dioxide as powdered form as used in the reinforcement. The silicon carbide and zirconium dioxide (2, 5 wt %) were added as the reinforcement in the process of bottom stir casting to prepare composites in the study [6].

Figure 1: Aluminium Metal

Figure 2: Silicon Carbide

Figure 3: Zirconium Dioxide Powder

Characterization of zirconium dioxide, silicon carbide reinforcement aluminum metal matrix composite by using bottom stir casting method.

Table 2: Physical Properties of Materials [6]

S.NO	Properties	AL6061T6	S_IC	ZrO_2
1	Melting point (^0C)	582-652	1750	2715
2	Density (g/cm^3	2.7	3.21	5.68
3	Tensile strength (MPa)	290	240	115
4	Elongation (%)	16	2	
5	Yield strength (MPa)	240	210	106

EXPERIMENTAL PROCEDURE

Fabrication of Aluminium-Silicon Carbide Composite Material

In this experimental study, we have considered aluminum 6061T6 as metal matrix and silicon carbide as reinforcement materials (SIC) as weight 2%, 5% respectively. Composite is prepared by using bottom stir casting as shown in the figure. AL6061T6 is taken in the form of small pieces for the experimental study.

The electric furnace set as a temperature about 650^0C-750^0C with the control panel. The aluminum small pieces are placed inside the crucible. The graphite crucible aluminum small pieces now placed inside the furnace and heated reaches its melting point, metal reaches into the liquid state the slag formed on the surface will be removed slowly. The silicon carbide powder is preheated in the furnace at 300^0-350^0 temperature to remove the moisture in silicon powder. After that now add the silicon carbide in the AL6061T6 liquid state by stirring the graphite rod at speed 450-500 rpm. The stirring is done very slowly for 10 to 15 minutes because it will be mix properly. Composite was cast into a die in required diameter and length. To provide enough time for cooling and then the sample was taken out.

Fabrication of Aluminium-Zirconium Dioxide Composite Material

In this experiment, we have considered Aluminum 6061T6 as metal matrix and zirconium dioxide as reinforcement material (Zro2) as wt 2%, 5%. Composite is produced using bottom stir casting method. AL6061T4 is taken in the form of a cylindrical rod for this experiment.

The electric furnace set at a temperature about 6500C-7500C with control panel. The small pieces aluminum is placed inside the crucible. The graphite crucible containing rod placed in a furnace and now heated reaches it melting point, metal reaches into liquid state the slag is formed in the surface will be removed slowly. The zirconium dioxide powder is preheated with the help of furnace at 3000-3500 temperature to remove the moisture. Add zirconium powder in the aluminium 6061 liquid states by stirred graphite rod at speed 450-500 rpm. Stirring is done very slowly for 10 to 15 minutes because it mixes properly. To provide enough time for cooling and then the sample was taken out.

Table 3: Sample Composition

S.NO	Composite Material	Percentage
1	AL6061T6+2% silicon carbide	98%+2%
2	AL6061T6+5% Silicon carbide	95%+5%
3	AL6061T6+2% zirconium dioxide	98%+2%
4	AL6061T6+5% zirconium dioxide	95%+5%

Figure 4: Bottom Stir Casting

Figure 5: Muffle Furnace

EXPERIMENTAL TESTING DETAIL

Rockwell Hardness Testing

Rockwell hardness scale is a hardness scale based on the indentation hardness of the material. The Rockwell test determines the hardness if the materials. According to ASTM-18 standard hardness test is performed in scale A and scale B with load 60kgf and 100 kgf, in a dwell time 6 second. The composite material is tested on A and B scale with a diamond indenter with 1/16 ball indenter. The result of the Rockwell hardness test is 4 trials of each sample.

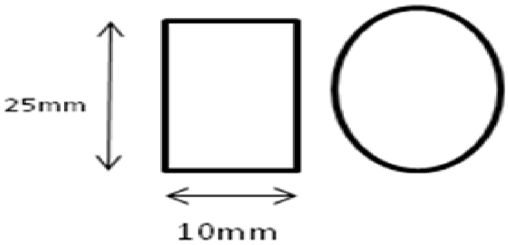


Figure 6: Hardness Testing Sample

Impact Testing

Impact testing, which determines the toughness, impact resistance, fracture resistance. Impact test are two types

- Charpy test
- Izod test

Charpy test is also known as v- notch test which determine the amount of energy absorbed by the material during fracture. Charpy test is conducted ASTM E-23 which determines the toughness. It makes necessary the specimen strike the hammer impact strength 123kj in case of a charpy test. The charpy test potential energy converted to kinetic energy. The results of the material is ductile or brittle in nature.

Izod impact testing is an ASTM E-23 standard method of determining the impact resistance of the material it makes necessary the hammer is strike impact strength 164j time 6 second in case of izod test.

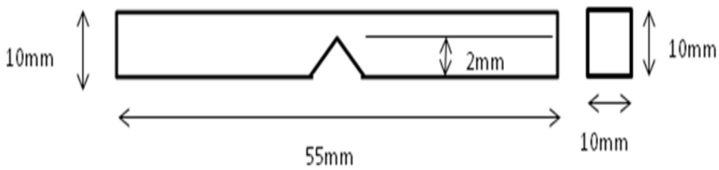


Figure 7: Charpy Test Specimens

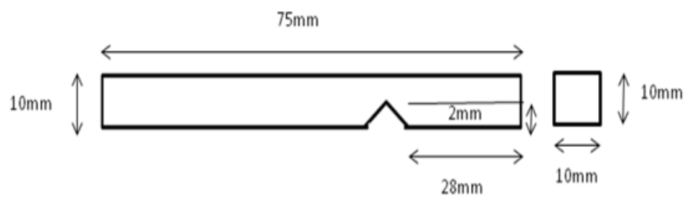


Figure 8: Izod Test Specimens

Brinell Hardness Testing

The brinell hardness test is performed to determine the hardness of the material like metal and alloy. The composite specimen is prepared as per standard as brinell hardness testing ,ASTM A370 the indenter having dimension 1 inch square is forced in the surface of the sample. Standard load is applied 250kgf maintained at constant for 8 seconds then removed. The result brinell hardness number has calculated the impression of the indentation.

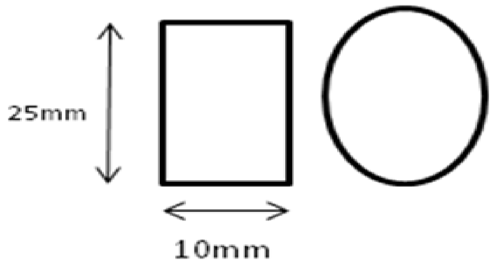


Figure 9: Brinell Hardness Sample Dimensions

Tensile Strength Test Specimen Detail

Tensile test is also known as tension test which determine the material properties. In which a sample is subjected to control a tension until failure. The tensile test is performed on (UTM) universal testing machine of 1000 KN capacity.

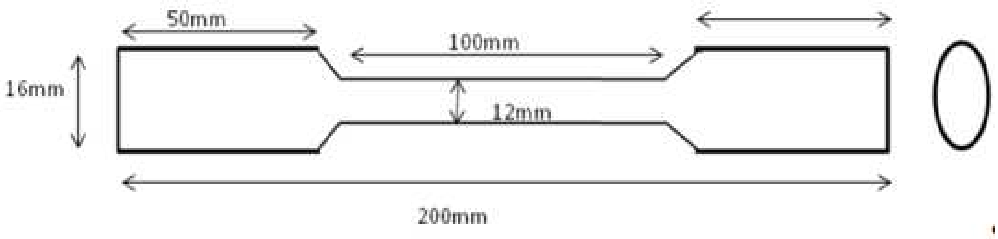


Figure 10: Tensile Test Specimens

Scanning Electron Microscope and Microstructure

SEM images of the prepared composites where it can observe to confess the distribution of reinforcement silicon carbide, zirconium dioxide and aluminum metal matrix. The picture analyzer is used to the experimental study the arrangement of the silicon carbide and zirconium dioxide particle within aluminum metal matrix. The microstructure being observed that we can use microscope, but before doing the sample polished with the help of emery paper of different grade like (200, 400,700,1400,1600,2000 etc).

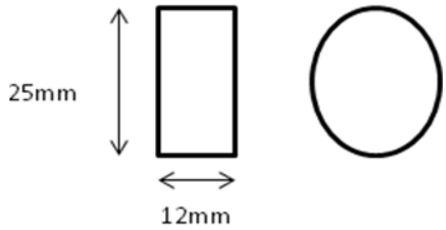
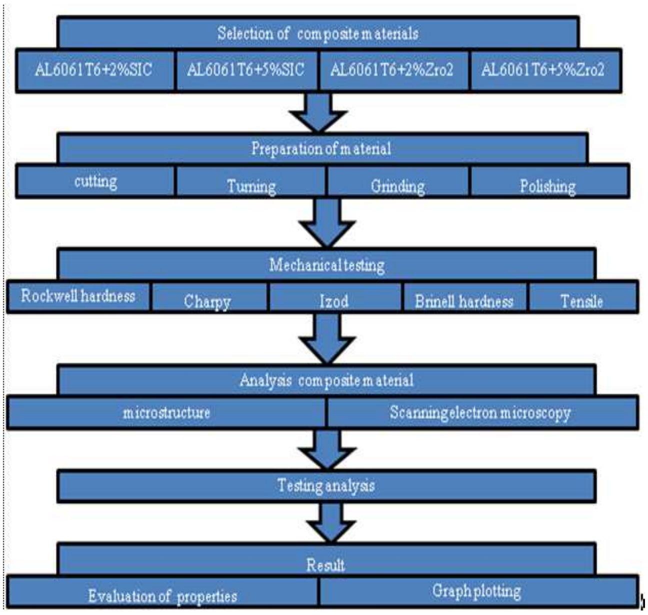


Figure 11: Dimensions of Sample SEM and Microstructure

Flowchart of Sample Prepared in Lathe Machine



RESULTS AND DISCUSSIONS

Hardness Test

The Rockwell experiment is done. The results have been carried out in table 4 in A Scale reading and compared by result table 5 which the compared material is selected in table 1 after studies of components. The experimental value and compared material value plotting in graph shown in figure 13. After the hardness test, sample shows in figure 12.

Table 4: Rockwell Hardness Result

S.No	Sample	Trial 1	Trial 2	Trial 3	Mean
1	AL6061T6+2%SIC	80.2	87.4	88.5	85.37
2	AL6061T6+5%SIC	90.6	85.2	87.4	87.73
3	AL6061T6+5%ZRO2	87.2	93.3	80.1	86.86
4	AL6061T6+2%ZRO2	82.1	87.3	80	83.13

Table 5: Comparing Hardness Properties [7]

S. No	Sample	HRA
1	En19	64.45
2	100%AL7075	60
3	100%AL6061T6	40
4	AL5182	21
5	AA5454	24

Figure 12: Pictorial View of Sample for Hardness Test

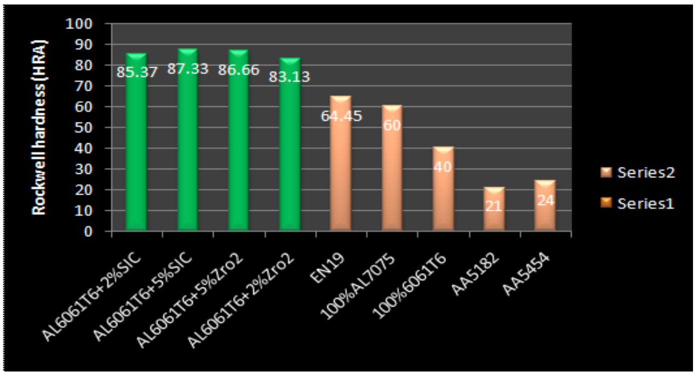


Figure 13: Comparative Bar Chart (Hardness HRA)

Impact Test

The charpy experiments have been conducted by the sudden load. The experimental results indicated in table 6 and compared material which is selected in table 1 comparing value tabulated in table 7. Charpy test which determines the impact energy of the material. The experimental value and compared material value graph shown in figure 15. And sample shows in figure 14.

Table 6: Impact Strength Result Value

S. No	Name of Composite Material	Charpy Test (j)
1	AL6061T6+5%ZrO2	71
2	AL6061T6+2%ZrO2	67
3	AL6061T6+5%SIC	70.2
4	AL6061T6+2%SIC	66

Table 7: Comparing Material Impact Test Value

S. No	Materials	Charpy Test (j)
1	AA5182	65
2	EN19	90
3	100%AL7075	69
4	100%AL6061T6	100
5	AA5454	65

Figure 14: Pictorial View of Sample for Charpy Test

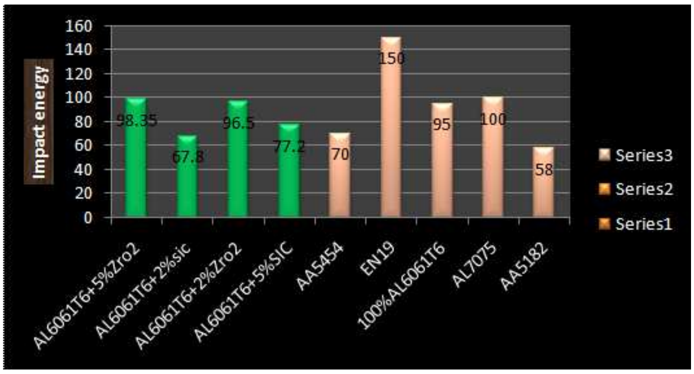


Figure 15: Comparative Bar Chart Impact Energy (j)

Izod Test

The test is conducted in a sudden load. The result is tabulated in table 8 and comparing the material result in table 9. The izod sample shows in figure 16 and graph shown in figure 17.

Table 8: Izod Test Result

S. No	Sample Name	Izod Value
1	AL6061T6+5%Zro2	32
2	AL6061T6+2%Zro2	24
3	AL6061T6+5%SIC	33
4	AL6061T6+2%SIC	22

Table 9: Comparing Material Value

S No	Material Name	Izod Value
1	100%AL6061T6	30
2	EN19	46
3	AL7075	38
4	AA5454	29
5	AA5182	23

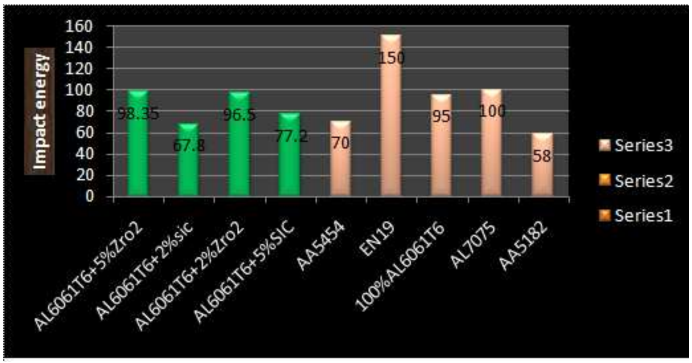


Figure 16: Comparative Bar Chart Impact Energy (j)

Figure 17: Izod Test Specimen

Brinell Hardness Test

Hardness test which determines the ability of the material to resist wear, indentation. The hardness test is done in the brinell hardness ASTMA370. The result can be obtained in table 8 and comparing material selected in table 1 comparing value can be insulated in table 9 brinell hardness graph shows in figure 19 and the sample shows figure 18. Each sample has two trial.

Table 8: Brinell Hardness Result

S. No	Sample name	Trial 1	Trial 2	Mean
1	AL6061T6+5%Zro2	97.4	99.3	98.35
2	AL6061T6+2%SIC	70.2	65.4	67.80
3	AL6061T6+2%ZrO2	97.6	95.4	96.50
4	AL6061T6+5SIC	79.3	75.1	77.2

Table 9: Comparing Material Result

S.No	Material	Brinell Hardness Value
1	AA5454	70
2	EN19	150
3	100%AL6061T6	95
4	100%AL7075	100
5	AA5182	58

Figure 18 Sample Brinell Hardness

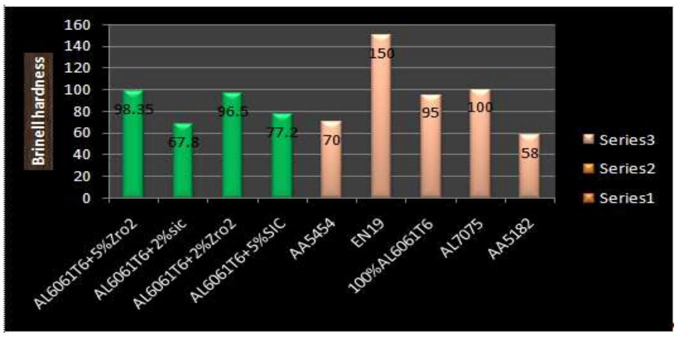


Figure 19: Bar Chart Hardness

Tensile Testing

Tensile test is done in the UTM universal testing machine. The result shows a tensile test in table 10. Table 11shows comparing material properties taken from table 1. Sample shown in figure 20 after the test and figure 21 is formed by UTM MACHINE.

Table 10: Tensile Test Result

S. No	Properties	AL+2%Zro2	AL+5%SIC	AL+5%ZrO2	AL+2%SIC
1	Ultimate tensile load (KN)	6.040	5.040	6.000	3.520
2	Ultimate tensile strength (MPa)	53.405	44.563	53.053	31.124
3	Displacement at Ult. Load (mm)	4.300	5.400	2.400	4.000
3	Maximum displacement (mm)	5.200	6.100	4.400	4.300
4	Percentage elongation (%)	6.000	6.100	2.000	8.000
5	Percentage reduction area (%)	43.750		30.556	15.972
6	Breaking load	3.080	2.760	4.040	2.440
7	Breaking stress	27.233	24.404	35.729	21.574
8	Yield load	0.000	0.000	4.240	2.320
9	Yield stress	0.000	0.000	0.037	0.021

Table 11: Comparing Material Properties

S. No	Sample	Tensile Load	Tensile Strength	Elongation
1	AL7075	5.220	50.887	7-8
2	EN19	220.600	1110	68.550
3	AL6061T6	5.320	50.034	7.8
4	AA5454	5.326	260	14
5	AA5182	4.200	31.952	4

Figure 20: Tensile Test Specimens

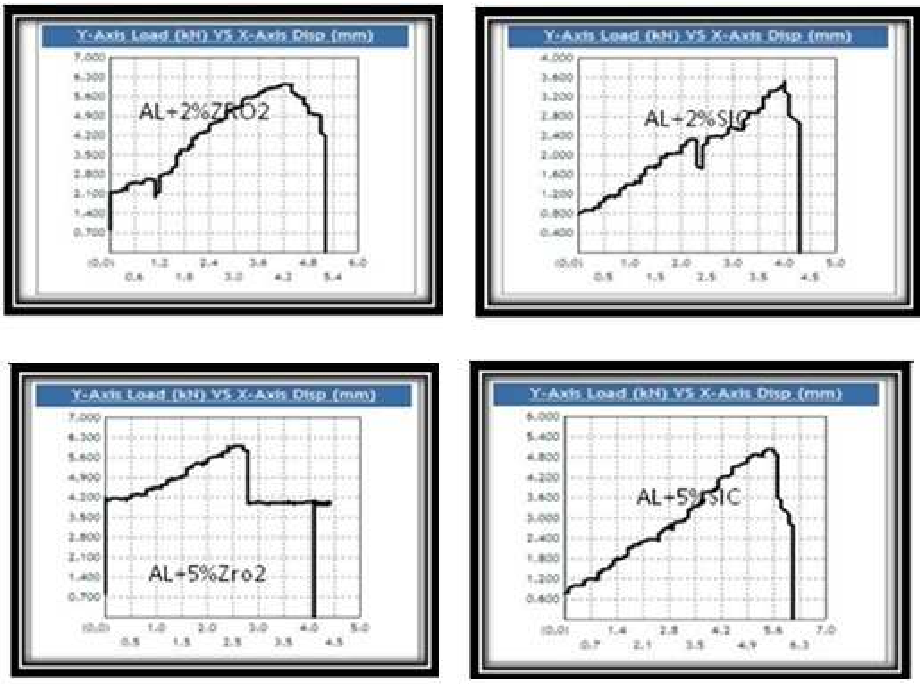


Figure 21: Graph Generated UTM Machine

Microstructure and Scanning Microscopy Result

The optical micrographs of the fabricated AL6061T6 metal matrix and SIC, Zro2 Reinforcement material. It can be seen that the silicon carbide and zirconium dioxide particle (2% weight) are not uniformly distributed but well joined with the aluminium matrix. Silicon carbide and zirconium dioxide particle play an important role during the solidification of the composite melt. As the reinforcement particles 5% weight fraction increases the microstructure image become darker and dense. In this arrangement of reinforcement, particles will uniform and well be bonding with aluminum matrix. The presence of zirconium dioxide and silicon carbide reinforcement particle in the microstructures will impede the movement of continued. As the result will form improve the mechanical properties as well as tensile strength improves. The degree of strength produced depends upon the size of particles, refined the grain of matrix aluminum and was properly bounded to the matrix. The microstructure images show in figure 22.

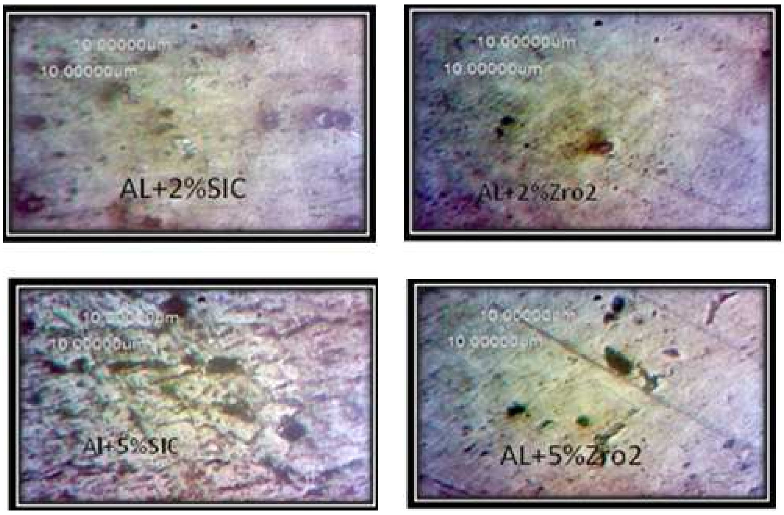


Figure 22: Microstructure Result

Figure 23: Scanning Electron Microscope Specimens

Scanning Electron Microscopy

SEM micrographs of the specimens of AL6061T6/SIC and zirconium dioxide AMCs presented in figure 22. The fracture micrograph of the fabricated AL6061T6/SIC and zirconium dioxide aluminium matrix figure SIC5%,ZrO2 shows smaller size compared to the 2% SIC, Zro2 and aluminum matrix. The fracture surface presents a flat appearance which indicates macroscopically brittle fracture and microscopically ductile fracture. The silicon and zirconium reinforcement particle in the matrix increases the grain size, which reduce the ductility. It can be observed that the silicon carbide and zirconium dioxide particle intact in places on the fracture surface which gives better bonding between the aluminum matrix and silicon carbide and zirconium dioxide particle.

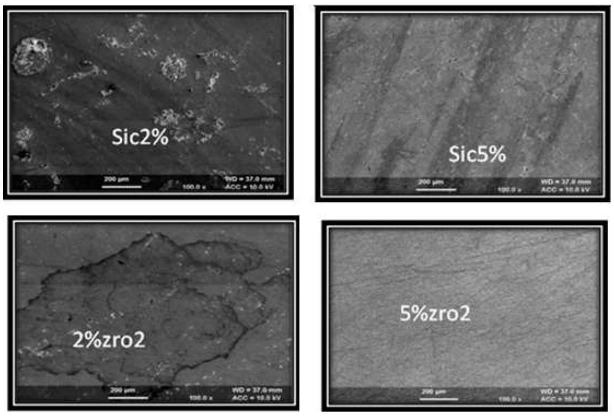


Figure 24: SEM Micrograph of AL6061/2, 5% SiC and ZrO2 at Magnification 200um

SEM micrographs the distribution of silicon carbide and zirconium dioxide particle in the aluminum matrix should be uniform of fairly homogeneous, but from the observation of SEM images of AL6061T6/5wt.% silicon carbide and zirconium dioxide AMC at higher magnification is presented in fig SIC, Zirconium 5% as compared to silicon and zirconium 2%. The figure reveals the details of interface existing between the aluminum matrix and silicon carbide, zirconium dioxide. The SEM images of 2%SIC, ZRO2-AL- composite. Shows that uniform distribution of silicon and zirconium particles are well bounded in the aluminum matrix. These happen due to provide improper time for contact between reinforcement particle and aluminum matrix because of the poor wetting behavior of sic particle in aluminum. But the silicon and zirconium dioxide particle increases up (5wt. %) distribution of reinforcement particles still non uniform and in well bonding with aluminum matrix. The presence of silicon carbide and zirconium dioxide particle in the SEM will impede the movement of continued. The result will obtain better improvement of mechanical properties like tensile strength, impact strength. There are no pores are seen around silicon carbide and zirconium particle which are bounded in a matrix.

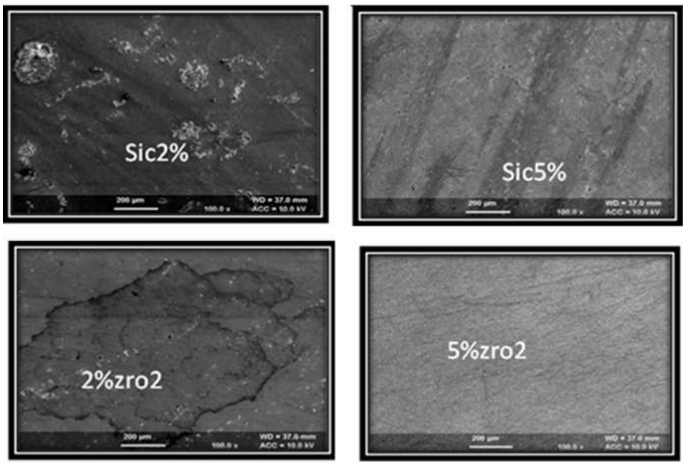


Figure 25

CONCLUSIONS

In the present work study, the AL6061T6/SIC, ZrO2 AMCs were successfully prepared by bottom stir casting process with silicon and zirconium content (2% and 5%) in aluminum matrix. The microstructure, Rockwell hardness, brinell hardness, impact strength, the tensile strength of the fabricated composite were studied. It is based on the experimentation we have concluded that in this study the experiments were conducted to identify the composite material that is not used in at present time at that components manufacturing. We find the results AL6061T6/SIC wt 5% the mechanical properties good as compared to pure aluminum and steel. AL6061T6/SIC wt.5% is found the best composite material for manufacturing of cylinder liner, and engine valve in the automobile components. As well as composite AL6061T6/ZrO2 wt 2%, which are generally used in the manufacturing of automobile parts because maximum tensile strength and high ultimate tensile load observed at 6.040 N/mm2 and density will be low at that time. For disc brake and rotor have a maximum brinell hardness was observed at 5% zirconium powder with 95% Aluminium is 98.35

For piston and disc brake have high strength so AL6061T6/SIC wt 2% is good for manufacturing. Al6061T6/SIC 5% Also has wear characteristics good because theincrease in silicon carbide % content in aluminum matrix increases the wear resistant results 5% SIC content aluminum matrix showed minimum wear loss as compared to pure aluminum steel. So it is good for bearing stud nut bolt and gearbox manufacturing. A propeller shaft should have high strength and low

density so AL6061T6/SIC wt 2% is better than as well as AL6061T6/SIC ZrO2 wt5% can be used. AL6061T6/SIC wt5% better for brake rotor and connecting rod because more hardness observed 87.73N/mm2 and high toughness.

The SEM and microstructure properties we conclude that the optical micrograph of the composite produced by stir casting method shows a fairly uniform distribution of silicon and zirconium particulates in the AL6061T6 matrix. The effect of silicon carbide and the zirconium dioxide content of microstructure SEM were analyzed. The distribution of silicon and zirconium in the aluminum matrix was fairly uniform and homogenous. The distribution of SIC/Zro2 particle observed to be intra granular. The matrix alloy and were properly bonded to the matrix so it can improve the mechanical properties as well as tensile strength and good for manufacturing in automobile components. So composite is lighter in weight and the best replacement for manufacturing. Scanning electron microscopy images of all the specimens subjected tensile strength is examined.

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